PROVINCIAL POPULATION AND HARVEST ESTIMATES OF MOOSE IN BRITISH COLUMBIA

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ABSTRACT: Provincial population and harvest estimates of moose in British Columbia, Canada were assessed over a 28-year period from 1987 to 2014. The population generally remained stable, whereas the licensed hunter harvest declined gradually by about half despite constant hunter effort. The annual population estimate ranged from a low of 157,000 moose in 1994 to a high of 190,000 in 2011, with an overall mean of 172,000 ± 9900 (SD). In 2014, the relative status of hunted populations within 7 wildlife administrative units was 1 increasing, 3 stable, and 3 in decline. The mean annual licensed harvest was 10,038 ± 2137 (SD) moose, and the mean harvest rate was 6 ± 1.3% (SD). In December 2013, British Columbia initiated a 5-year (2013–2018) research project to identify factors contributing to the decline of the moose population and licensed harvest.

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Key words: *Alces alces*, British Columbia, harvest, moose, population

Periodic updates of moose (*Alces alces*) abundance are necessary to assess management objectives (Brown 2011), evaluate sustainable harvest (Timmerman and Buss 2007), and to provide information to the public. Assessing licensed harvest concurrent with population estimates should provide better understanding and explanation of population fluctuations over time. Moose population estimates are also used for comparison among jurisdictions to assess patterns of broad-scale population trends. In North America, there is current concern for declining populations in southern parts of moose range (Murray et al. 2006, Lenarz et al. 2009), whereas populations remain stable in other areas (Murray et al. 2012). Explanations for population change include human-caused habitat alterations (Rempel et al. 1997), climate change (Rempel 2011), and a combination of natural and human-influenced variables (Murray et al. 2006, Brown 2011).

Moose in British Columbia are highly valued for food, social, and ceremonial purposes by First Nations, for recreational and commercial harvest opportunities by licensed hunters, and for wildlife viewing. Specific management objectives for moose harvest are to manage for First Nations use, support a sustainable licensed hunter harvest, and provide for diverse hunter opportunities (BC FLNRO 2015). Assessment of abundance and licensed harvest estimates is required to ensure that harvest levels are sustainable (Hatter 1999), objective information is available for management decisions, and to provide accurate information on the status of moose to stakeholders and the public (BC FLNRO 2015). The purpose of this paper is to provide an overview of the population abundance and licensed harvest of moose in British Columbia from 1987 to 2014.

STUDY AREA

British Columbia is an ecologically diverse province (Meidinger and Pojar 1991) where moose are widely distributed (Fig. 1) and occupy a range of landscapes including wet coastal habitats, dry interior forests, cold northern forests, and montane habitats (Eastman and Ritcey 1987). At the provincial scale, moose co-exist with several ungulate species including bison (*Bison bison*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*), and caribou (*Rangifer tarandus*) (Shackleton 1999). The main predators of moose are wolves (*Canis lupus*), grizzly bears (*Ursus arctos*), and black bears (*U. americanus*), with cougars (*Puma concolor*) important in southern British Columbia (Spalding and Lesowski 1971). Bull hunts were mostly open seasons, with antler restrictions or limited entry hunts occurring between 15 August and 30 November. Antlerless harvest was largely restricted to limited entry hunts with some general open seasons for calves in select areas. Seasons for antlerless moose occurred between 1 October and 10 December (BC MOE 2010).

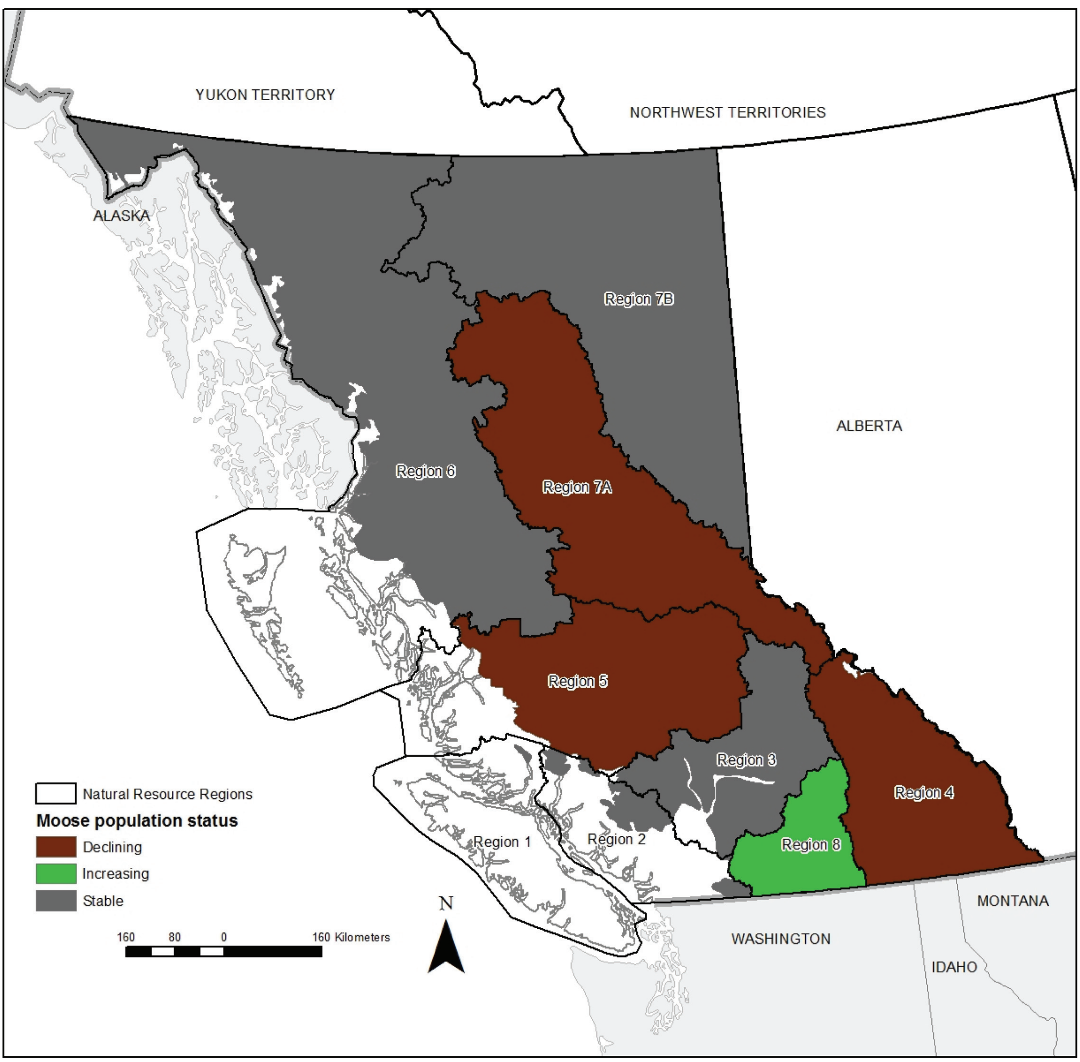

Fig. 1. Distribution and population status (i.e., stable, increasing, decreasing) of moose in 7 wildlife administrative units in British Columbia, Canada, 2014.

Hunting seasons were generally available throughout the distribution of moose with the exception of Regions 1 and 2 which have few moose (i.e., <130 combined) and National Parks (<1% of land area) where licensed hunting is prohibited.

METHODS

Moose population estimates were produced by regional biologists in 7 wildlife administration units (Regions; Fig. 1) from 1987 to 2014, and then combined for a provincial total. There were 3–5 year intervals between estimates to provide time to assess potential changes in moose abundance at the provincial scale. Minimum and maximum estimates were derived from 2000 to 2014 because of the need to convey uncertainty when comparing estimates between years. These estimates were developed using the best available information from a combination of sources including aerial surveys, big game stock assessments, and expert opinion.

A third degree polynomial was used to fit a long-term population trend line to the abundance estimates from 1987 to 2014. The polynomial was preferred to a linear or log-linear trend line because the polynomial was sensitive to fluctuations in population size. In the 7 regions where moose were hunted, the trend (stable, declining, increasing) was determined from the change in abundance estimates and the slope of the trend line from 2011 to 2014.

Aerial surveys were the most important source of information because they provided data for estimation of population size, density, and composition. All surveys were required to follow provincial standards that are based on defensible scientific methods (RISC 2002). Stratified random block surveys were used (Gasaway et al. 1986) or modified to include habitat-based stratification (Heard et al. 2008). A standard sightability correction factor was applied to account for detection probability based on research with radio-marked moose in central British Columbia (Quayle et al. 2001). Aerial surveys were required to conform to standards for accuracy and precision (1-α) and to produce a 90% CI with allowable error (±15–25%). The frequency of stratified random block surveys was based on available funds and prioritization criteria which included time since last survey, First Nations concerns, impact to hunter opportunity, population objectives, and if the survey was part of an ongoing monitoring program (BC FLNRO 2015). Aerial composition surveys were also conducted to determine bull:cow and calf:cow ratios; ground-based surveys following provincial standards were used occasionally (RISC 1998, D' Eon et al. 2006).

Big game stock assessments were used to help estimate population size and sustainable harvest levels as outlined in the provincial moose harvest management procedure (BC MOE 2010). These assessments helped maximize information from aerial surveys and hunter harvest (Griffiths and Hatter 2011), and incorporated uncertainty associated with extrapolating area-based survey results to regional population estimates. They helped determine the maximum allowable mortality and accounted for First Nations harvest and road/rail mortality where available. Population models were one component of big game stock assessments and were occasionally used in the regional population estimates by fitting annual licensed harvest data to periodic survey data (White and Lubow 2002). Population variables used in the models generally included annual licensed harvest data, post-hunt population size and composition, overwinter survival, and recruitment rates (Griffiths and Hatter 2011). If empirical information was lacking about a population, regional biologists used a broad spectrum of expert opinion including field information gathered from resident hunters and trappers, guide-outfitters, First Nations, and other resource professionals. This information was gathered during a variety of forums and locations including formal stakeholder meetings and informal discussions.

Licensed harvest of moose was monitored annually from 1987 to 2014 with a provincial resident hunter survey, and guide declarations for non-resident hunters. Harvest information from First Nations was not part of the provincial hunter survey and was largely unknown (BC FLNRO 2015), with the exception of certain First Nations communities that voluntarily provided information. Estimates of licensed hunter harvest (resident and non-resident combined), hunter days, and hunter numbers were available, all with 95% confidence intervals (CI). These estimates were produced from mail-out questionnaires sent to a random sample of resident hunters; from 2008 to 2014 an average of 13,003 questionnaires were mailed annually with an average response rate of 61%. Licensed harvest rates were calculated from the provincial population estimate for a given year and the average of the 3 nearest harvest estimates; 2014 was an exception when the average of the 2 nearest harvest estimates were used because of delay in the 2015 estimate. Combined resident and non-resident hunting license sales from 1989 to 2014 were used to further measure hunter interest.

RESULTS

The mean annual population estimate of moose in British Columbia was 172,000 ± 9900 (SD) from 1987 to 2014. Annual estimates were relatively stable ranging from a low of 157,000 moose in 1994 to a high of 190,000 in 2011 (Fig. 2). The minimum and maximum estimates (i.e, from 2000 to 2014) reflected varied levels of uncertainty (Fig. 2). The 2014 estimates varied among the 7 regions with hunted populations: 3 were considered stable (Regions 3, 6, and 7B; Figs. 1 and 3), 3 were declining (Regions 4, 5, and 7A; Figs. 1 and 4), and one region was increasing (Region 8; Figs. 1 and 3).

The mean annual licensed harvest from 1987 to 2014 was estimated as 10,038 ± 2137 (SD). Total harvest declined gradually by about one-half during this period, yet hunter effort (average days hunted) remained stable (Fig. 5). The mean annual licensed harvest rate from 1987 to 2014 was 6 ± 1.3% (SD), ranging two-fold from a high of 8% in 1987 to a low of 4% in 2011. From 1987 to 2014, the mean number of licensed hunters (resident and non-resident combined) was 33,721 ± 4292 (SD) that spent 273,622 ± 32,521 (SD) days of hunter effort (Table 1). The mean annual hunting license sales was 39,815 ± 4158 (SD) from 1989 to 2014 and varied minimally from 1993 to 2014 (Table 1).

DISCUSSION

The annual moose population in British Columbia during 1987–2014 was relatively stable, averaging 172,000. In 2014 hunted populations were stable in 3 regions, decreasing in 3 regions, and increasing in one. Although both provincial and regional population estimates had varied levels of uncertainty, they remain important for resource managers to address management objectives (BC FLNRO 2015), and to inform First Nations, stakeholders, and the general public about the status of moose in British Columbia.

The estimation error was partially responsible for the uncertainty reported in the abundance estimates. The variation in the population estimates may reflect the varied abundance and composition of local and regional predators (Ballard and Van Ballenberghe 2007), human-altered landscape change (Rempel et al. 1997) which may enhance forage quality and quantity while facilitating predator and hunter access to moose, and variation in licensed and unlicensed harvest levels (Timmerman and

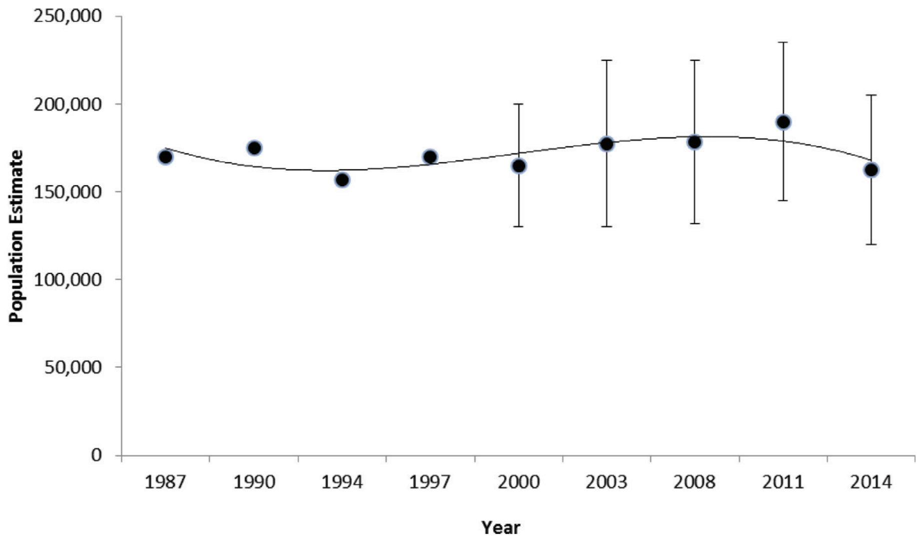

Fig. 2. Provincial population estimates of moose and trend line derived from inventories, population modeling, and expert opinion from 1987 to 2014 in British Columbia, Canada. Minimum and maximum ranges in population estimates are presented from 2000 to 2014.

Buss 2007). Other factors such as weather, disease, parasites, and accidents including road and rail mortality also influence local moose abundance. The quality of data used to develop the population estimates could also be improved with increased financial and logistical support that would provide more aerial surveys over a broader geographical area.

Of most concern to stakeholders were recent (2008–2014) population declines in Regions 4, 5, and 7A (Fig. 4). In two regions (Region 5 and 7A) the moose declines coincided with a mountain pine beetle (*Dendroctonus ponderosae*) epidemic (Chan-McLeod 2006) which led to increased salvage logging and associated road building. This type of landscape change can presumably alter the spatial dynamics of moose, predators, and hunters, ultimately influencing moose abundance and harvest rate. Although moose should benefit from salvage logging through increased forage production (Janz 2006), those benefits are not immediate and may be offset by higher harvest and predation due to easier access afforded by high density of roads and cutblocks (Ritchie 2008).

To address the recent moose population declines, British Columbia initiated a provincially-coordinated research project in 2013 to evaluate the landscape change hypothesis (Kuzyk and Heard 2014) and to increase science-based information for moose management. To date, unpublished data from this research has provided no evidence that low pregnancy rates, infectious disease, or parasites are influencing the moose population (H. Schwantje, BC FLNRO, personal communication). Similarly, preliminary adult survival rates are within the limits of a stable moose population (92 ± 8% in 2013–2014 and 92 ± 5% in 2014–2015; Kuzyk et al. 2015). In southeastern British Columbia (Region 4), declining forage production in older burns and wolf predation are believed limiting to moose population growth (Stent 2009, 2012). Further, in an attempt to reduce predation of an endangered caribou population, the local moose density was reduced which lowered wolf abundance in a small

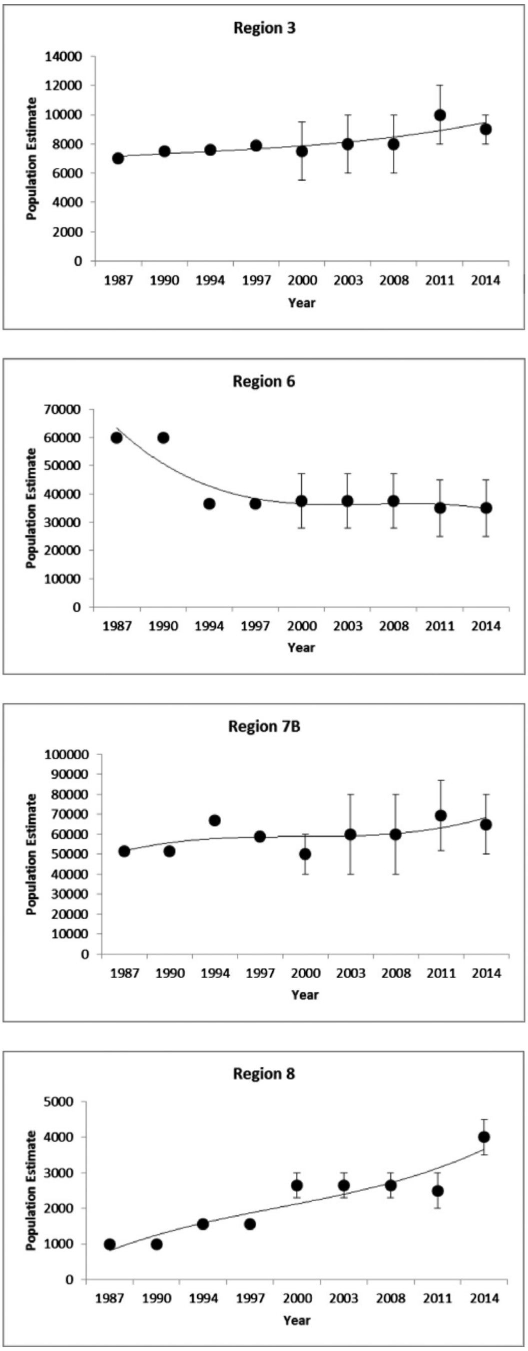

Fig. 3. Regional moose population estimates and trend lines in Regions 3, 6, 7B, and 8 as derived from inventories, population modeling and expert opinion, 1987–2014, British Columbia, Canada. Minimum and maximum ranges in population estimates are presented for 2000–2014.

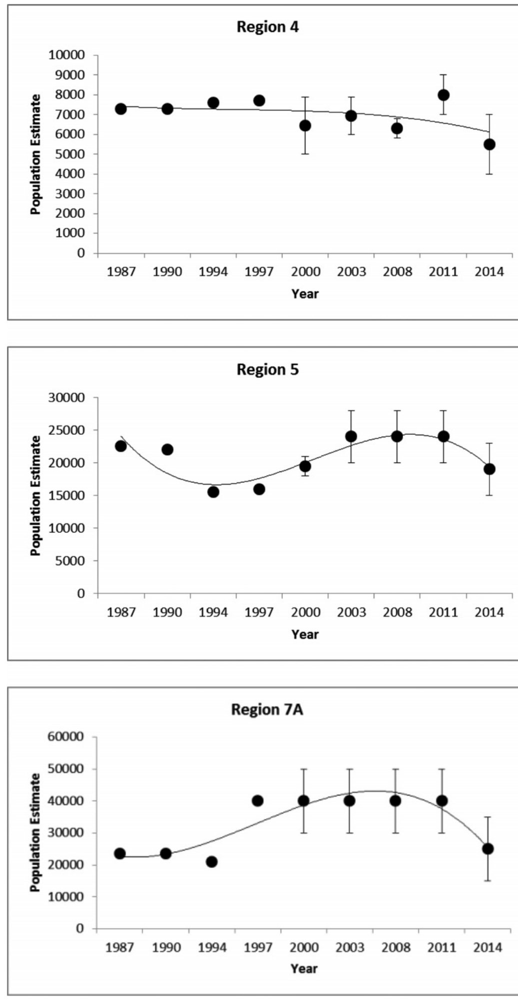

Fig. 4. Regional moose population estimates and declining trend lines in Regions 4, 5, and 7A as derived from inventories, population modeling, and expert opinion, 1987–2014, British Columbia, Canada. Minimum and maximum ranges in population estimates are presented for 2000–2014.

portion of the region (~6,375 km^2) (Serrouya et al. 2011, Serrouya 2013).

Given stakeholder and public concern for declining moose populations, it is important to maintain a balanced, provincial-level assessment and approach that also addresses regions with stable or increasing populations. The large northwestern (Region 6) and northeastern (Region 7B) regions with stable

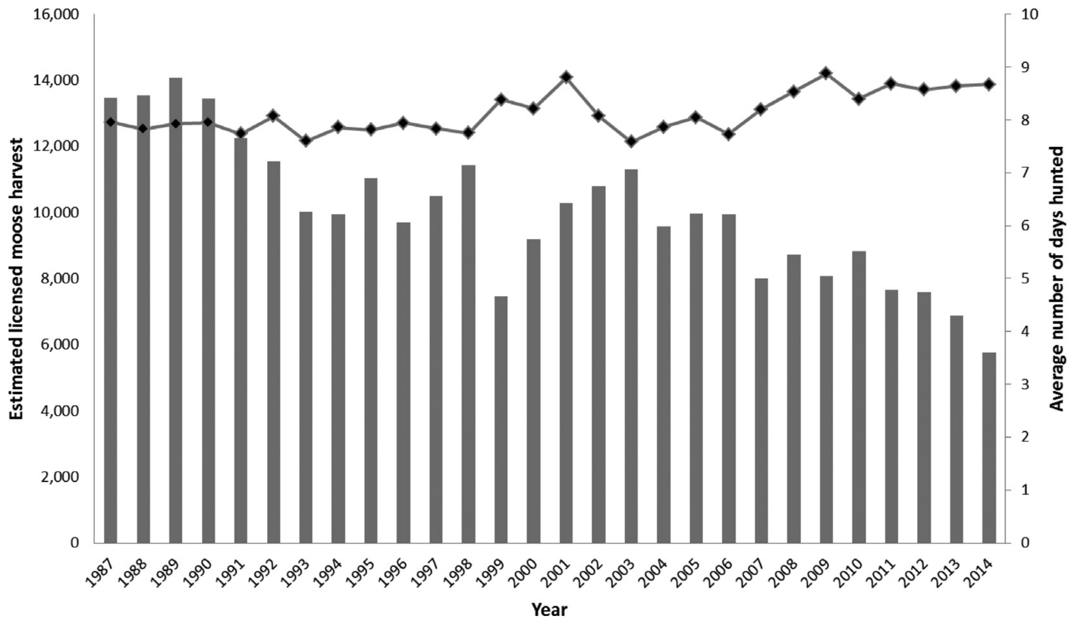

Fig. 5. Annual estimates of provincial moose harvest and hunter effort (average days hunted) by licensed hunters, British Columbia, 1987–2014.

moose populations are more remote than those in the southern half of the province and have not undergone landscape change that presumably facilitates hunter and predator access. These regions also experienced little impact from the mountain pine beetle outbreak compared to the central interior regions (Region 5 and 7A). The one stable population in the south was largely affected by the mountain pine beetle and salvage logging, but had lower wolf density compared to northern regions (BC FLNRO 2014, Kuzyk and Hatter 2014). The increasing population in the southern region (Region 8) overlapped with a recolonizing wolf population (BC FLNRO 2014). Further, this regional estimate was revised in 2013 with a habitat-based model (Gyug 2013) that may have amplified the estimated increase in abundance between 2011 and 2014.

The average (6%) and range (4–8%) of the provincial licensed harvest rate were mid-range of values reported throughout North America (2–16%; Crête 1987). More conservative harvest rates of 5% are recommended for northern systems where predation is believed to limit moose density (e.g., Yukon; Hayes et al. 2003), and may be appropriate in northern regions of British Columbia (Hatter 1999).

First Nations harvest of moose is thought to be broadly distributed province-wide (BC FLNRO 2015), but because no formal method exists to quantify First Nations harvest, the total harvest and rates reported here are underestimated and conservative. For example, local harvest may have been underestimated by up to 40% in Ontario by not accounting for First Nations harvest (Leblanc et al. 2011). Harvest information from First Nations in British Columbia would benefit future management efforts to ensure sustainable harvests for all users including First Nations, recreational hunters, and the guide-outfitting industry (BC FLNRO 2015).

An important outcome from this assessment was documentation of the gradual decline in licensed harvest by approximately half over 28 years from 1987 to 2014, despite constant hunter effort, indicating that the kill

Table 1. A summary of annual moose license sales and annual estimates of licensed hunters, hunter days, and moose harvest in British Columbia, Canada, 1987–2014.

Year	Licensed hunters	Licensed hunter days	Licensed harvest	License sales
1987	42,526	338,482	13,463	N/A
1988	42,679	334,246	13,539	N/A
1989	41,979	332,852	14,070	51,520
1990	42,104	334,718	13,457	50,367
1991	39,400	304,852	12,251	46,010
1992	38,973	314,613	11,557	45,289
1993	33,236	252,647	10,025	38,538
1994	31,423	247,039	9944	37,714
1995	31,778	248,281	11,047	38,018
1996	30,923	245,617	9701	35,948
1997	32,085	251,582	10,494	37,243
1998	35,617	276,206	11,438	41,089
1999	29,840	250,287	7459	35,612
2000	31,106	255,569	9182	36,221
2001	30,988	272,771	10,290	36,145
2002	31,829	256,975	10,803	37,010
2003	31,493	238,983	11,309	36,608
2004	27,293	214,743	9571	40,438
2005	31,498	253,619	9980	37,175
2006	32,010	247,409	9939	38,374
2007	31,719	260,126	8000	38,069
2008	31,368	267,654	8730	37,125
2009	32,880	291,920	8074	40,371
2010	32,242	270,781	8836	39,733
2011	32,324	280,931	7660	40,503
2012	32,277	276,699	7576	40,236
2013	32,420	280,133	6890	40,109
2014	30,172	261,677	5773	39,723
Mean	33,721 ± 4292	273,622 ± 32,521	10,038 ± 2137	39,815 ± 4158

per unit of effort (kills/hunter days) had declined. The disparity between these two trends may be related to difficulties producing accurate provincial population estimates that are driven by wide regional variation. Further, changes in the hunting season structure in the early 1990s reduced harvest levels in some regions (Hatter 1999), and similarly, a regulatory change allowing shared limited entry hunts in the early 2000s raised hunter effort through increased opportunity to hunt moose, without increasing harvest. Finally, although hunters maintained constant hunting effort as harvest declined, lower hunter success often reflects inclement weather and human disturbance that influence moose distribution. Given the number, frequency, and variable proportional influence of these factors, kill per unit of effort is probably not a reliable measurement to assess moose abundance in British Columbia (Hatter 2001). Further research should help identify the relationships among moose abundance, harvest rate, hunter effort, and landscape changes. It is important that regional and provincial moose abundance estimates and harvest data be monitored and evaluated on a regular basis to improve regional, provincial, and range-wide status of moose.

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